Phase I Project Summary

Firm: Physical Sciences Inc.
Contract Number: NNX13CP24P
Project Title: A Compact LIDAR for Aerosol Extinction Profiling from Small UAVs

Identification and Significance of Innovation:
It is increasingly recognized that the Arctic is a bellwether for climate change. Monitoring how aerosol distributions respond to climate forcing, especially changes affecting radiative transfer, will become increasingly important in refining climate models and predictions. NASA has launched several programs to increase observations of the region and incorporate findings into large scale climate models. Instrumented Unmanned Aircraft Systems (UASs) represent one means to efficiently measure the vertical profile of aerosol optical extinction over large areas. New instrumentation is required to enable routine measurements from UASs. In the Phase I program, we developed a conceptual design for a compact, eye-safe lidar payload for vertical profiling of aerosol extinction that will be deployable on a compact UAS like the SIERRA or BAT4. Our design concept is for a compact elastic backscatter lidar system that includes an innovative, low power consumption, compact Nd:YLF laser transmitter, along with highly compact, High Density Interconnect (HDI)-based system electronics. The lidar will provide range-resolved profiles of aerosol extinction by taking advantage of the maneuverability of the small UAS to acquire both horizontal and nadir measurements as a function of altitude. This approach bypasses the limiting assumptions inherent to retrieval of aerosol extinction profiles by backscatter lidars.

Technical Objectives and Work Plan:
The technical objectives of the Phase I program were to: (a) create a sensor architecture that will provide the needed measurement performance, (b) demonstrate that the lidar design can be packaged into a volume consistent with the payload resources of the target aircraft, and (c) create a plan for the demonstration of the sensor payload. To accomplish these objectives, the Phase I program tasks included:

1. **Kickoff Meeting** – Review program goals with NASA personnel including measurement metrics of lidar system. Review candidate aircraft. Review likely availability of candidate aircraft and opportunities for Phase II demonstration.
2. **Lidar design -** Create a technical design for the backscatter lidar to determine the transmit power, receiver aperture dimension, range, and range resolution.
3. **Payload engineering design** – Create a mechanical design for the lidar so that it is consistent with the available payload resources of the target aircraft. Create estimates for payload size, weight, and power.
4. **Payload-platform integration design** – Create interface control documents describing the interface between the sensor payload and the aircraft power and communications buses.
5. **Demonstration planning** – Create a testing and demonstration plan to streamline demonstration of payload in Phase II.

Technical Accomplishments:
We focused our design to be compatible with the SIERRA aircraft, based on discussion with NASA personnel at the Kickoff meeting. We created a design for a compact elastic lidar operating at 527 nm, transmitting 5 μJ pulses at 1 kHz from a 3 cm diameter aperture. The lidar has a transceiver design, which enables eye-safe transmission at the aperture. Return power is processed by single photon counting Si APD detectors. The system was designed for a range of 3 km. The photometric error on the return power at 3 km, with estimated background sky radiance, is ~ 5%. The estimated payload size is 2900 cm^3 and 3.6 kg. The payload is consistent with deployment on the SIERRA aircraft.

NASA Application(s):
The airborne lidar has value for applications requiring measurement of aerosols where sensor robustness and size are critical to performance. One relevant NASA program is the GEOstationary Coastal and Air Pollution Events (GEO-CAPE) mission. Another ongoing NASA mission of relevance is DISCOVER-AQ, which is also focused on aerosol distributions and air quality. A third relevant activity is the monitoring of volcanic emissions from the Turrialba Volcano, near San Jose, Costa Rica being led by David Pieri of JPL. This work has recently used instrumented Dragon Eye UAVs and hopes to use the SIERRA UAV in future work.

Non-NASA Commercial Application(s):
With its compact size and modest power requirements, the airborne lidar will enable measurements of aerosol optical extinction on a wider scale and at higher frequencies than are possible now. Non-NASA commercial applications are likely to include many ground-based applications such as visibility and Asian dust monitoring, hazardous volcanic ash cloud monitoring, regional air quality, human health assessments, and CBRNE detection. Introduction of the lidar into newly emerging networks for boundary layer meteorology may also be possible.

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